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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

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Additional inventors are being named on the separately numbered sheets attached hereto.

TITLE OF THE INVENTION (500 characters max)

INDUCTION SENSOR TECHNOLOGY

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ENCLOSED APPLICATION PARTS (check all that apply)

X	Specification Number of Pages	4		CD(s), Number	
X	Drawing(s) Number of Sheets	13		Other (specify)	
	Application Data Sheet. See 37 CFR 1.76				

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT (check one)

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This invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[X] No

[ ] Yes, the name of the U.S. Government agency and the Government contract number are :

Respectfully submitted, ATTORNEY DOCKET NO.: 006-526-000

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Gerry A. Blodgett

Gerry A. Blodgett

Induction Sensor Technology

Reference

1. United States Provisional Patent Application
   Taylor et al. "LINEAR POSITION AND MOTION SENSOR AND CIRCUIT"

Abstract

Refinements of the technology presented in Ref. 1 are disclosed. These are:

1. A circuit for converting frequency to voltage that is not the influenced by amplitude change of the frequency signal.
2. Coil - actuator arrangements are described that can have better linearity of output and extended measuring ranges.
3. A coil - actuator arrangement is described for measuring angular position.

Description of Circuit

Fig 1 shows the sensor circuit of the present invention. The circuit is a tuned oscillator circuit. The tuned oscillator circuit is comprised of an amplifier (U2) and two reactive components, an inductor L1 and a capacitor C4. The frequency of the oscillator is:

$$F = \frac{1}{2\pi\sqrt{LC}}$$

The amplifier U2 shown in Figure 1 is a high speed CMOS hex inverter. The resistor R2 is used to bias the input of the amplifier to compensate for the leakage current. The resistor R3 and capacitor C3 provide the feedback path. A transistor amplifier or operational amp will also work in place of hex inverter U2. The circuit shown in Figure 1 has a sine wave output signal. The inductor L1 is the coil in the sensors described here.

Fig 2a shows a prior art circuit commonly used with variable reluctance position sensing devices. With the prior art circuit an oscillator of fixed frequency feeds a signal to a variable reluctance device. As inductance changes with the prior art device the voltage through the inductor changes and this voltage is used to create output from the circuit. Commonly the voltage at the inductor is amplified. Thus the prior art circuit has voltage output.

Fig 2b is a depiction of the circuit of the present invention. In the circuit of the present invention the variable inductor which might be similar to that used with the prior art circuit is a component of the oscillator. Change in inductance of the inductor causes the oscillation frequency to change. The frequency of oscillation is taken as output. This frequency is passed to a counter or other device for the determination of output signal.

By using the variable frequency of the oscillator as output a higher output differential is attained as compared with the prior art circuit. Also, a better signal to noise factor is attained and the effect of environmental factors is lessened.

However, many control situations require voltage input. Fig 3 shows a circuit that encompasses the circuit of Fig 1 and produces voltage output that is regulated by the frequency of oscillation of the circuit of Fig 1. The circuit of Fig 3 converts the frequency output of the oscillator into a voltage that varies with the frequency.

Circuit functionality:

The positional sensor circuit processes the signal received from the sensor to an analog output. The output signal is a voltage relative to position with a refresh rate every oscillator cycle. In the process of describing the circuit functionality, the positional sensor circuit is divided into three groups. The groups include the sensor circuit(oscillator circuit of Fig 1), a timing management circuit and a signal output driver.

Sensor circuit:

This is the circuit of Fig 1. The sensor circuit is a closed loop oscillator with a frequency output dependent on position. Output is taken from U2 instead of between L1 and C4. The oscillator frequency is a square wave feeding the timing management circuit.

Time management circuit:

The time management circuit subdivides the sensor frequency (period) to make a time measurement per cycle. The first half cycle processes the measurement and the second half cycle is used to update the output signal.

There are two events that occur in the first half cycle, the first is to initialize the time measurement circuit to a preset state and the second is to make the time measurement. The frequency received from the sensor oscillator has an operating window from a minimum frequency to a maximum frequency. The time measurement is the difference

from the known maximum frequency (shortest period) to the received sensor frequency. The elapse time from the start of a cycle to the half cycle of the maximum frequency from the sensor is used to charge the timing circuit to a preset state. At the half cycle point of the maximum frequency to the half cycle point of the sensor frequency is the time measurement window. Fig 4 shows the waveform and is a graphical representation of the timing states.

The time measurement is achieved by a capacitor charged to a reference voltage and discharged at a set rate via a constant current source. Time is a function of voltage on the capacitor.

Signal output driver:

The signal output driver provides a voltage output signal referenced to the position of the sensor. The second half cycle of each period received by the sensor oscillator refreshes the output signal. The signal output driver circuit has high input impedance in order to provide minimum loading to the time measurement circuit. A sample and hold circuit makes the measurement at the designated time and holds the value between measurements. An output buffer isolates external circuit loading from the sample and hold circuitry.

Description of Sensors:

Background:

Variable reluctance position measurement devices operate because an electromagnetic field produced by a coil is influenced by an object in the field. The object that causes a change in the electromagnetic field is here called the actuator. In Fig 5 a coil assembly 1 is made of a coil of wire 3 wrapped on bobbin 2. The coil windings form a regular cylindrical shape. The actuator is cylindrical rod 4. The actuator rod is able to move along the axis of the coil. A graph of the relation between the position of the actuator 4 in the coil assembly 1 is shown by Fig 6. The full travel of the actuator rod within the coil windings produces an output that is more non-linear toward the ends of the travel and more linear in a central region that is the measuring range of the sensor. In many sensing applications it is desirable for the output of the sensing device to be more linear than the output shown by Fig 6.

Coil winding:

By distributing the turns of wire that make up the sensor coil so that there are more turns toward the ends of the coil as in Fig 7 and output graph for the sensor takes a more linear form as shown by Fig 8.

Actuator shape:

Fig 9 show a coil - actuator arrangement for detecting linear position. Actuator 1 has tapered end 2. The actuator may be made of metal and especially aluminum of copper plated steel or it may be made of soft ferrite. The actuator moves along the axis of the coil 3. As the volume of free space changes inside the coil the frequency output of the circuit of Fig1 changes. Buy judicious choice of the profile of the actuator the position vs. frequency character of the output of the sensor circuit can be adjusted. The output can have a graph that is more or less linear and also the range of detected motion can be longer than the length of the coil.

Fig 10 shows a particular coil – actuator geometry of the arrangement shown in Fig 9. Actuator 1 has tapered end 2 that is a modified parabolic shape. Fig 11 shows the output from the device of Fig 10. Fig 11 shows an output that is substantially linear over the measurement range. Also, the sensor range is longer than the length of the coil.

Fig 12 shows another coil - actuator arrangement for determining linear position. The actuator is cylindrical steel shaft 1 that has a copper plated section 2. The copper plated section has a leading edge that is a helix or other shape so that as the shaft moves axially in the coil more or less copper plated area is inside the coil. As more or less copper plated area is inside the coil windings the reluctance of the coil changes and the output of the sensor circuit changes. The shape of the leading edge of the copper plated section can be chosen so that the output of the coil is more or less linear and also the measuring range of the sensor can be longer than the length of the coil.

Angular variation

Fig 13 shows a sensor for determining angular position. Actuator 2 is rigidly attached to shaft 1. Coil 3 is held in fixed relation to the axis of shaft 1. The actuator may be made of metal and especially aluminum of copper plated steel or it may be made of soft ferrite. The shape of the actuator is chosen so that when the shaft rotates the actuator protrudes into the coil, and more specifically, it is shaped so that the cross section of the actuator material that is in the space inside the coil increases as the shaft is rotated in one direction and decreases as the shaft is rotated in the opposite direction. In this way, the inductance of the coil changes as the shaft is rotated. It is possible to find a shape for the actuator where the output of the circuit is substantially linear with regard to angular position. In Fig 13 the shaft rotates through an angle of approximately 90 degrees. This is appropriate for use in determining the angular position of a throttle shaft in an automotive throttle body. It is not intended here to limit the use of this type of device to angular displacement of 90 degrees. Other angular displacements can be attained by varying the shape of the actuator 2.

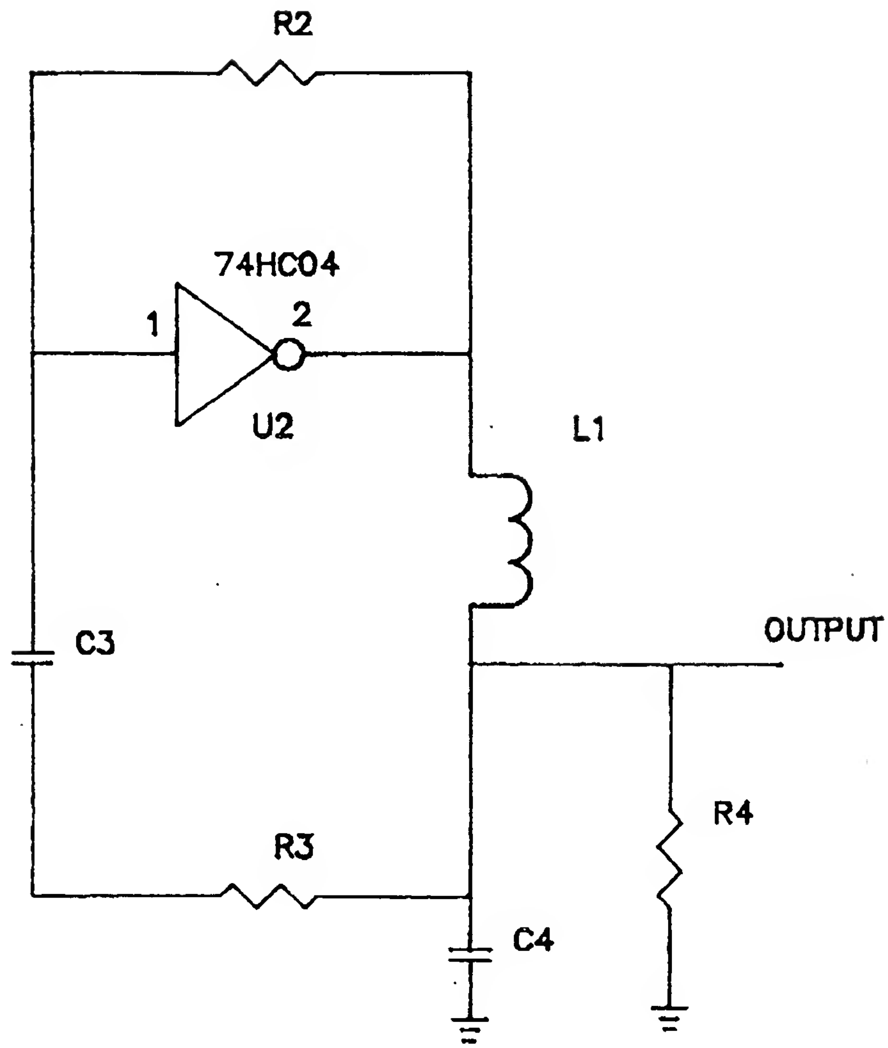


Fig 1

Fig 2a PRIOR ART CIRCUIT

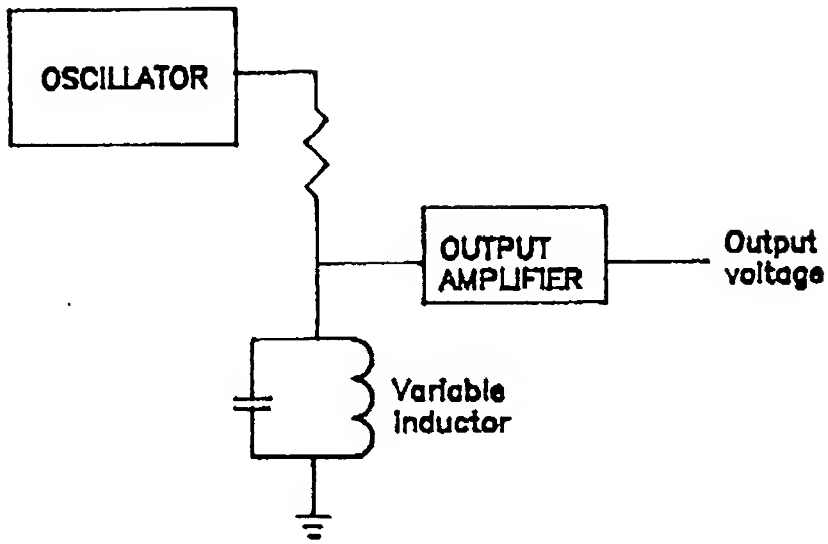
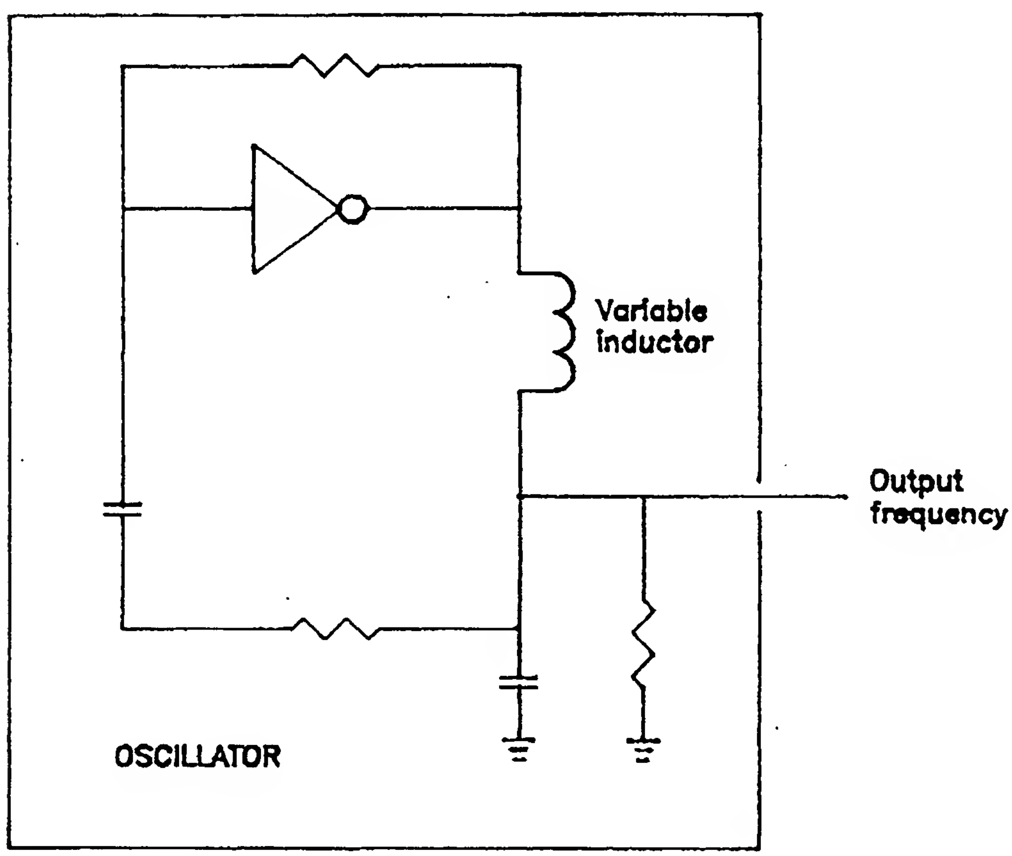


Fig 2b PRESENT INVENTION CIRCUIT



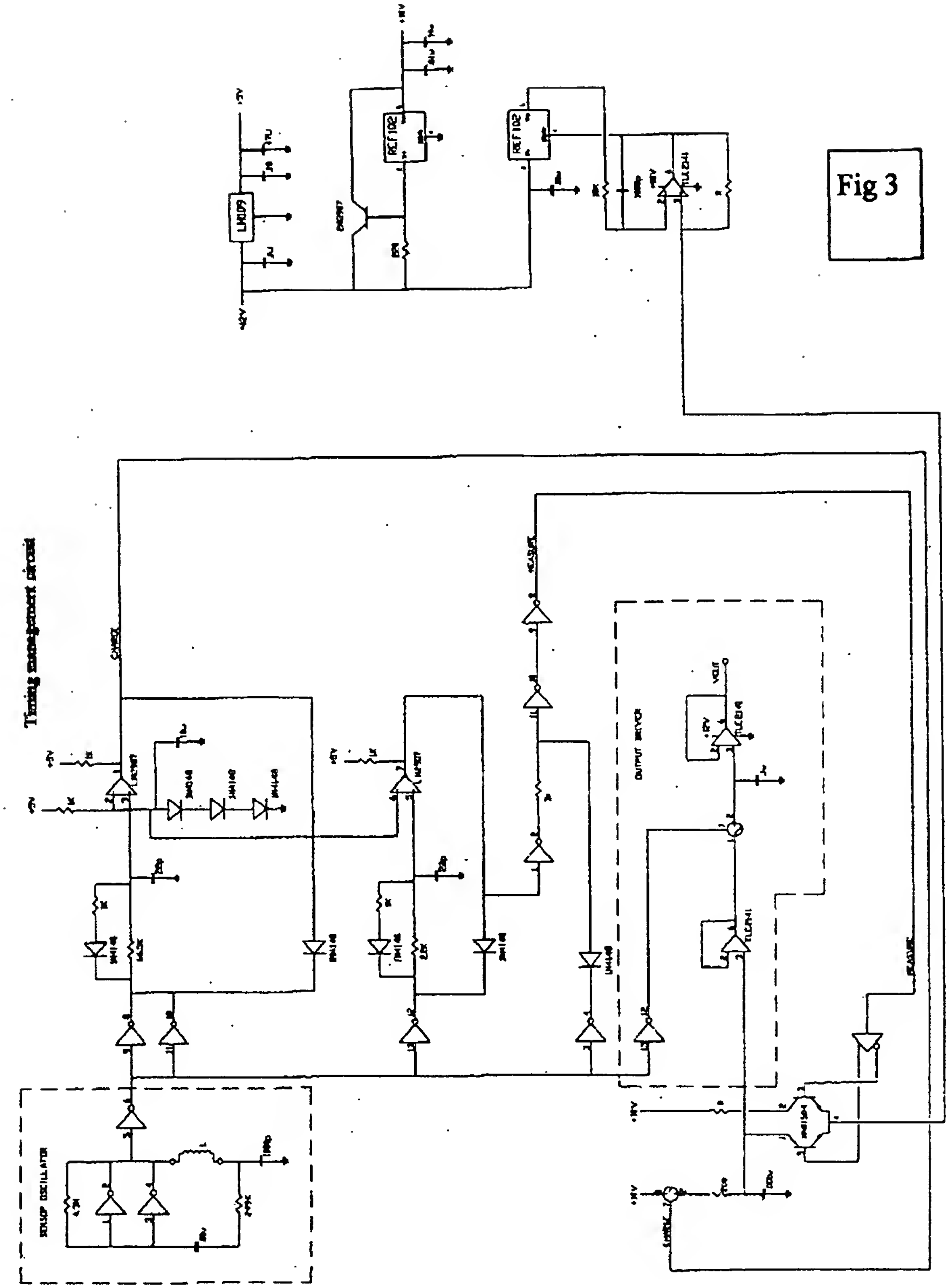


Fig 3

Fig 4

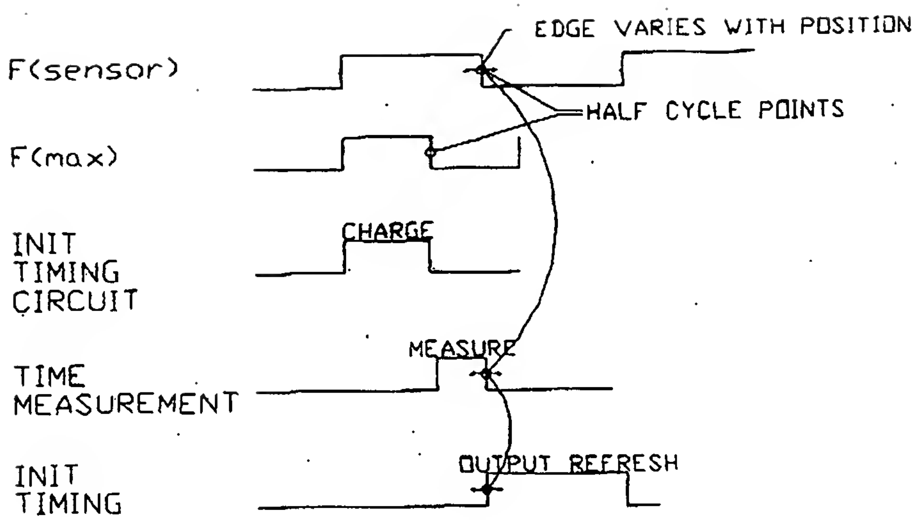

EDGE VARIES WITH POSITION
F(sensor)
HALF CYCLE POINTS
F(max)
CHARGE
INIT
TIMING
CIRCUIT
MEASURE
TIME
MEASUREMENT
OUTPUT REFRESH
INIT
TIMING

Fig 5

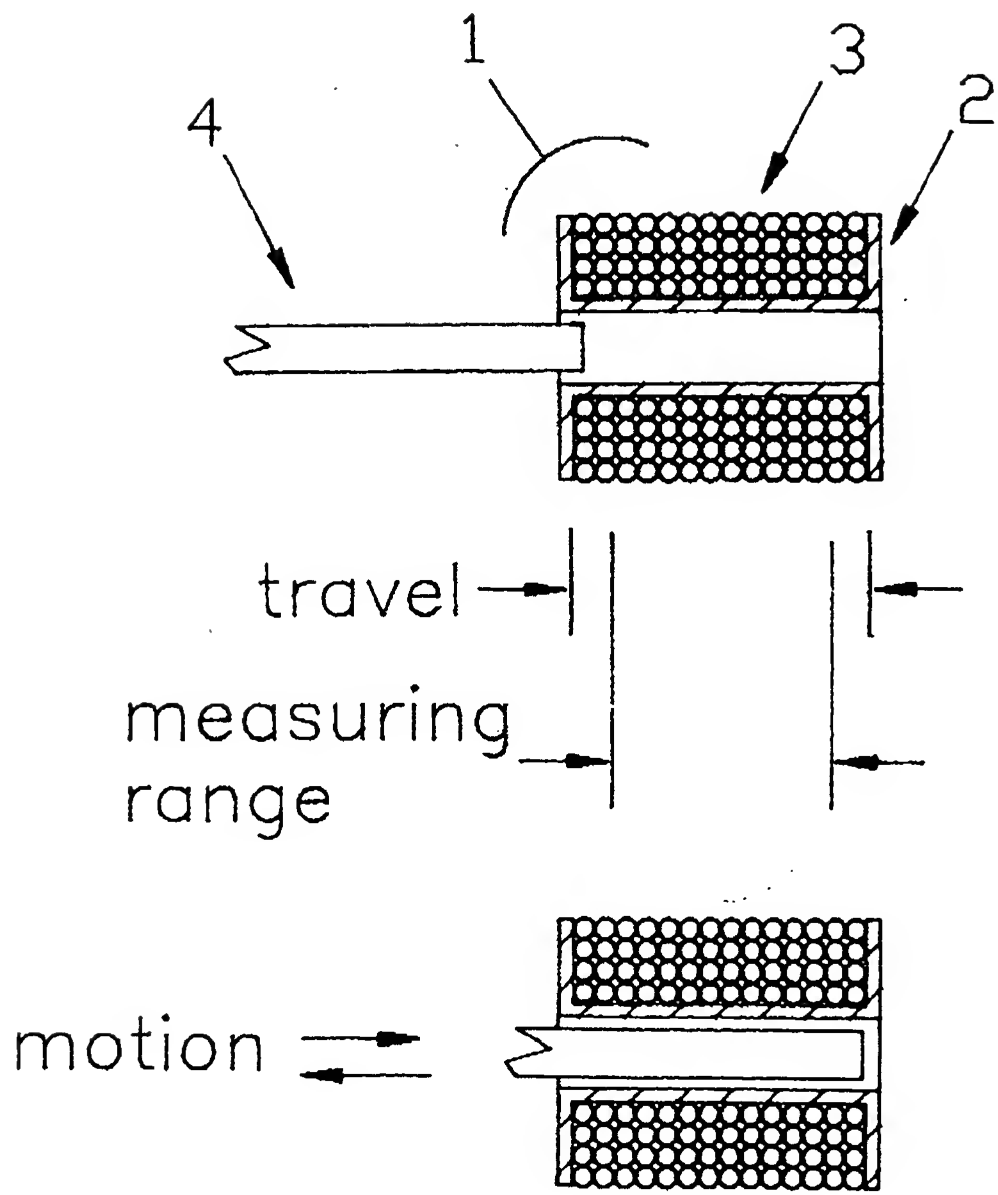


Fig 6

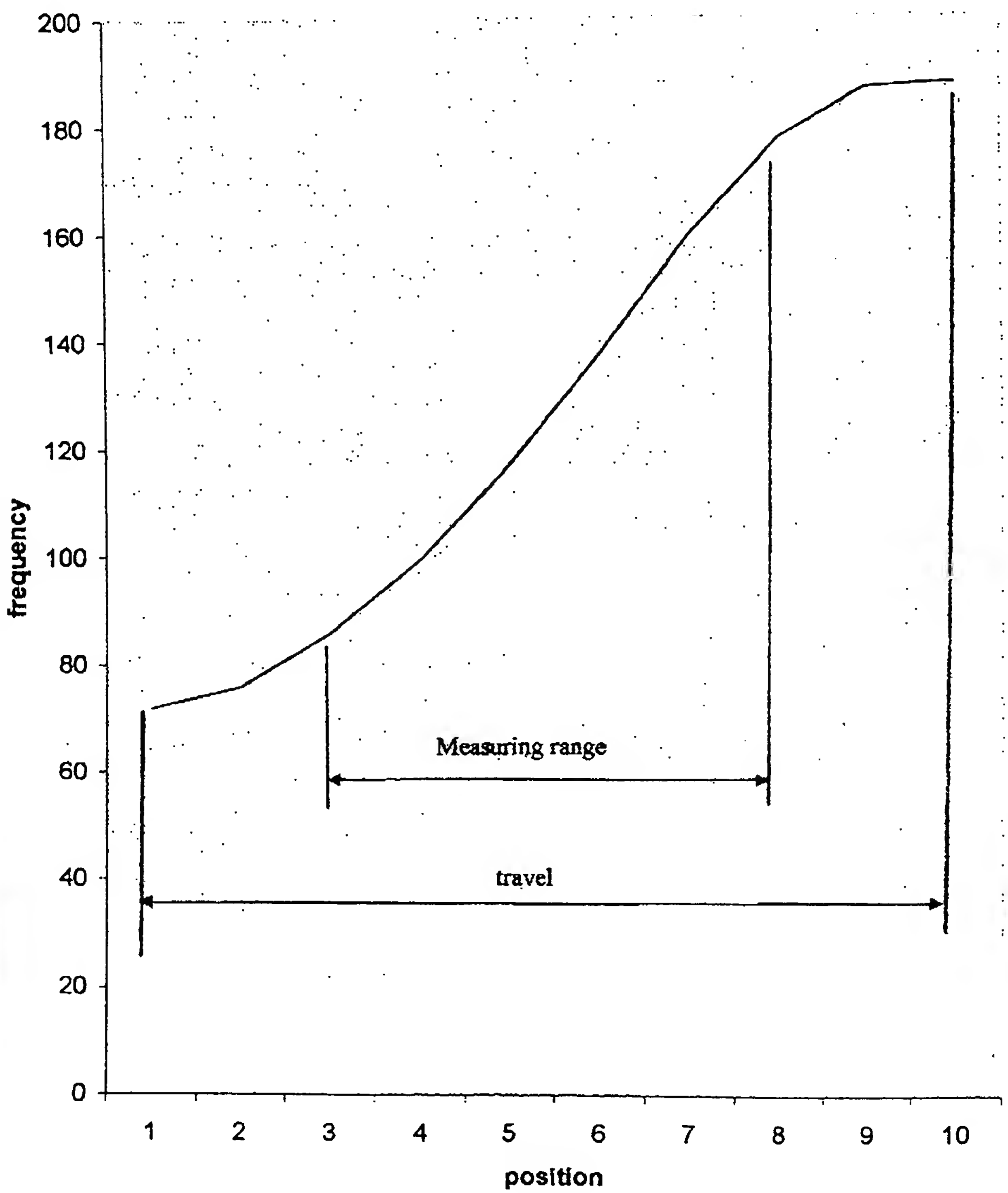

200
180
160
140
120
100
80
60
40
20
0
frequency
Measuring range
travel
1
2
3
4
5
6
7
8
9
10
position

Fig 7

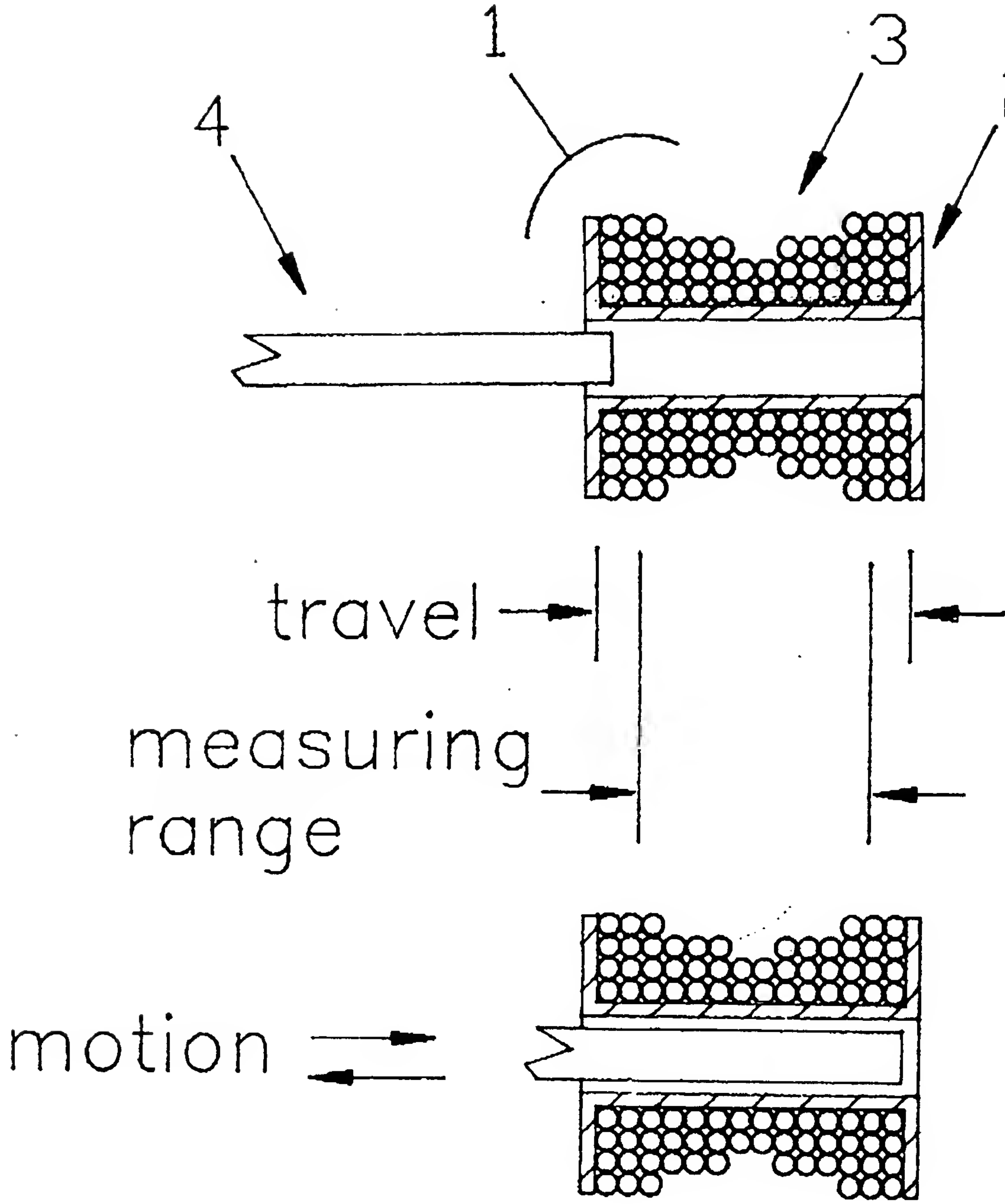
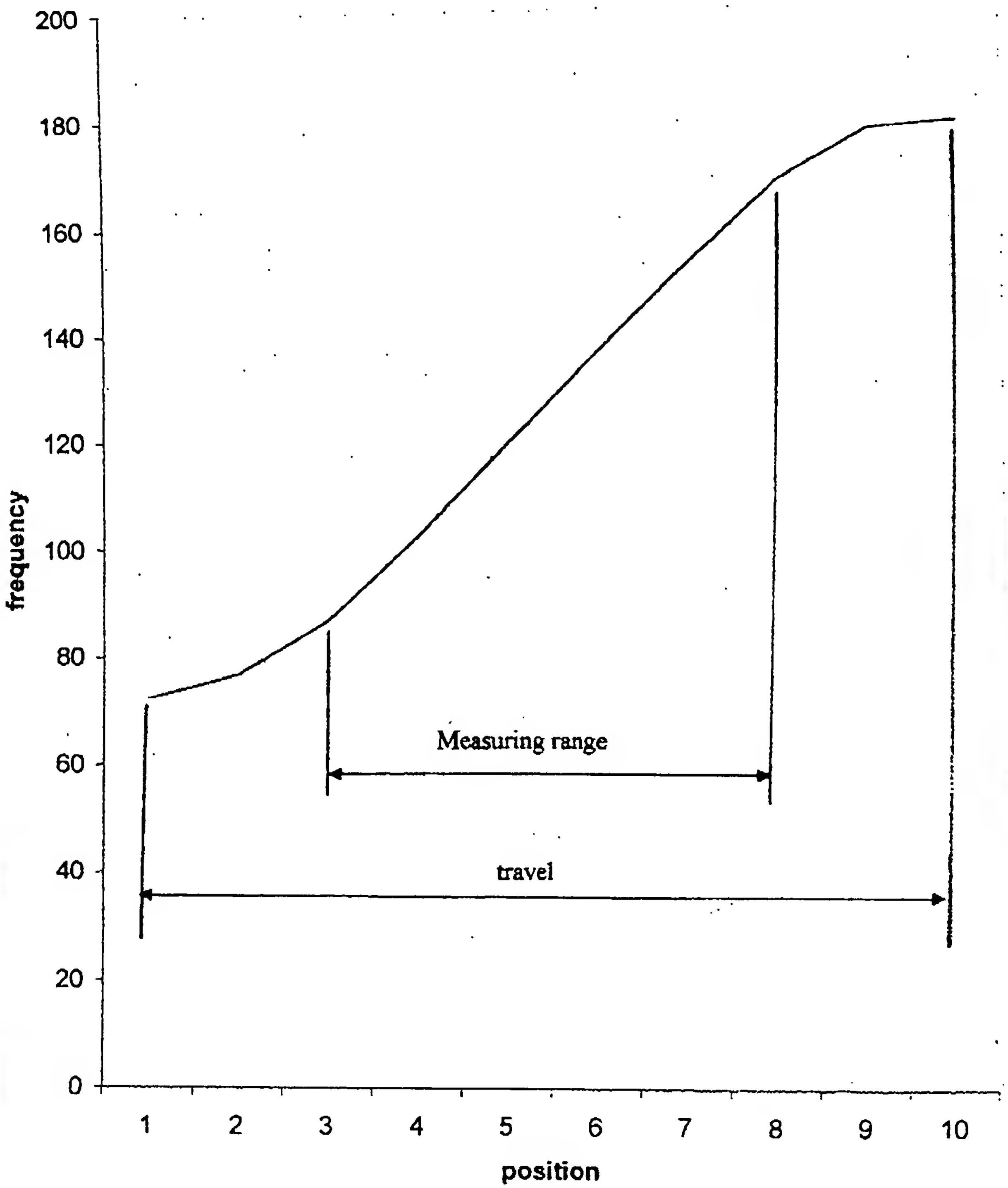


Fig 8


200
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frequency
Measuring range
travel
1
2
3
4
5
6
7
8
9
10
position

Fig 9

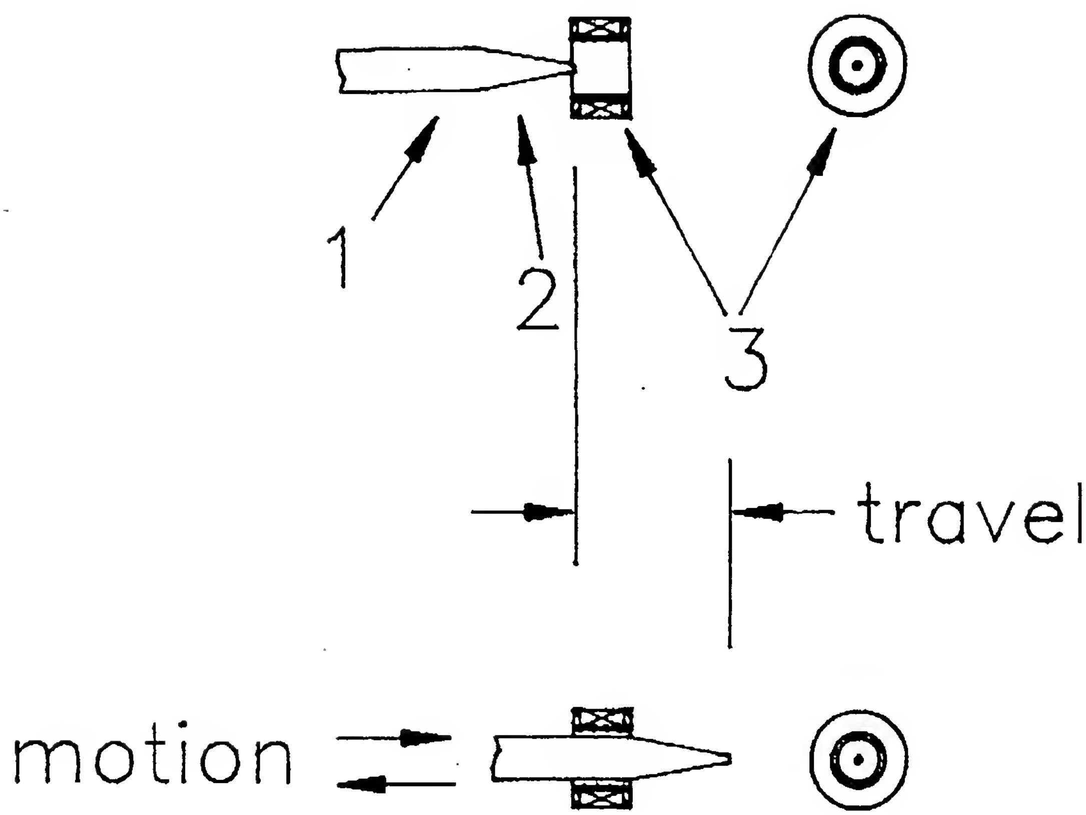


Fig 10

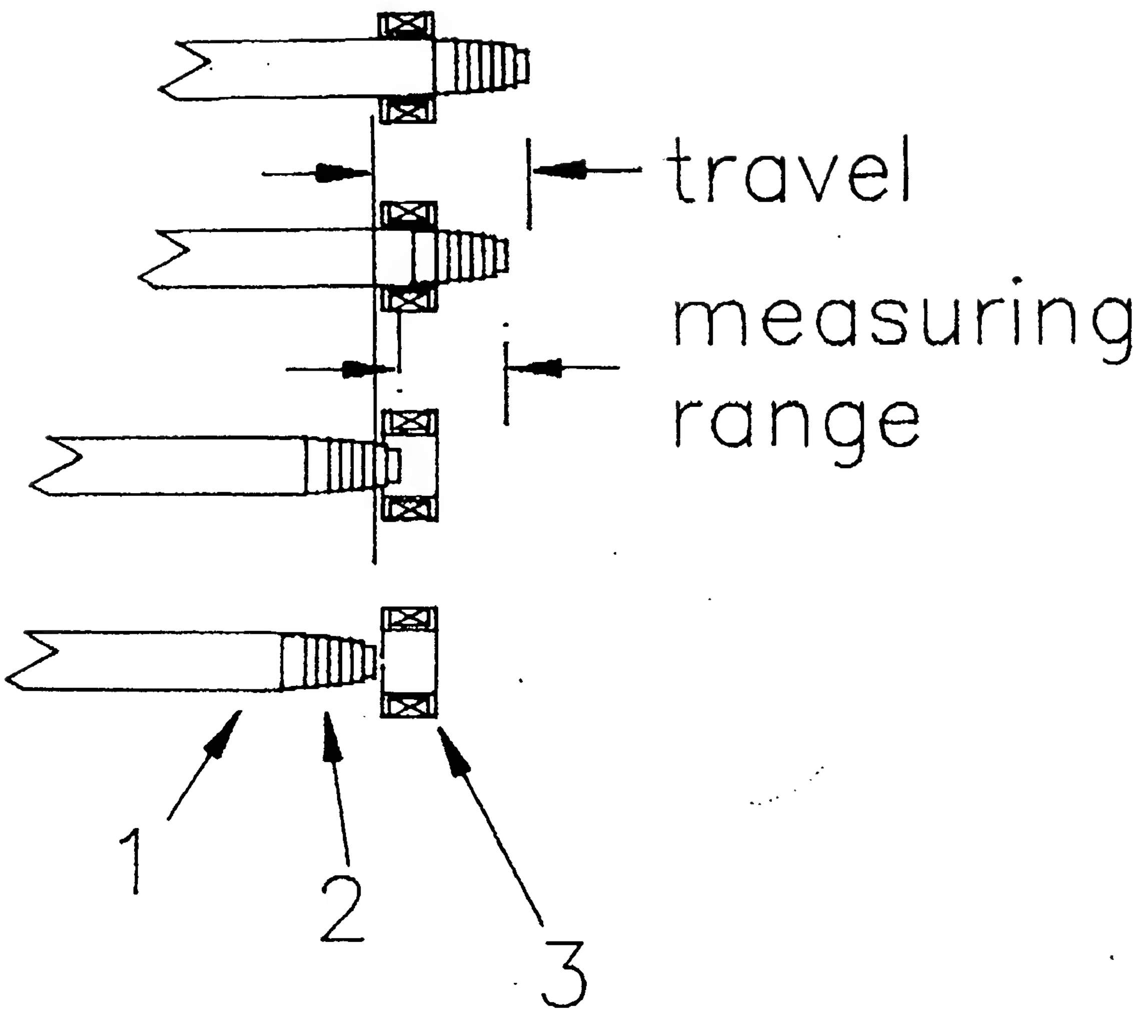
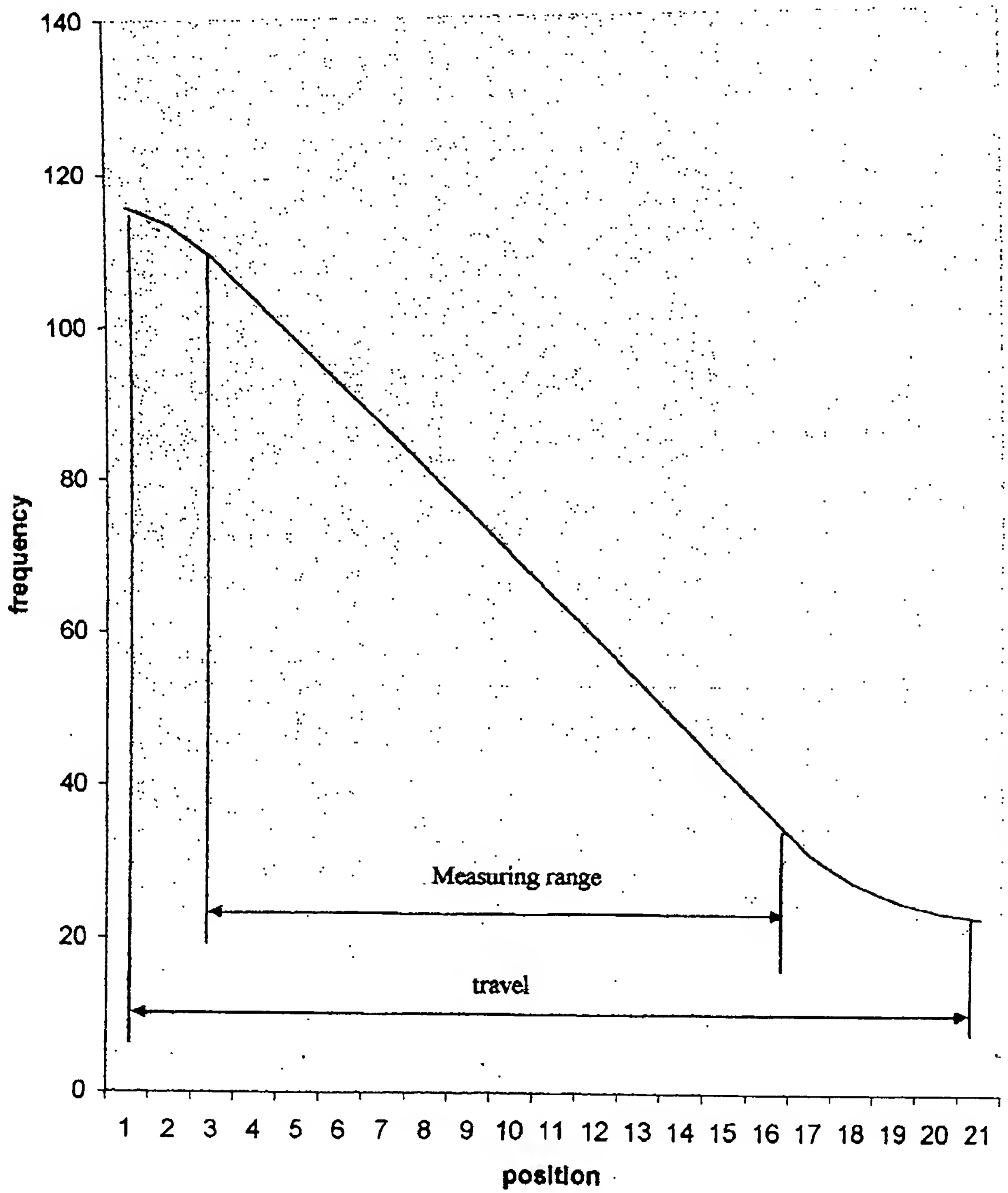


Fig 11



140
120
100
80
60
40
20
0
frequency
Measuring range
travel
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
position

Fig 12

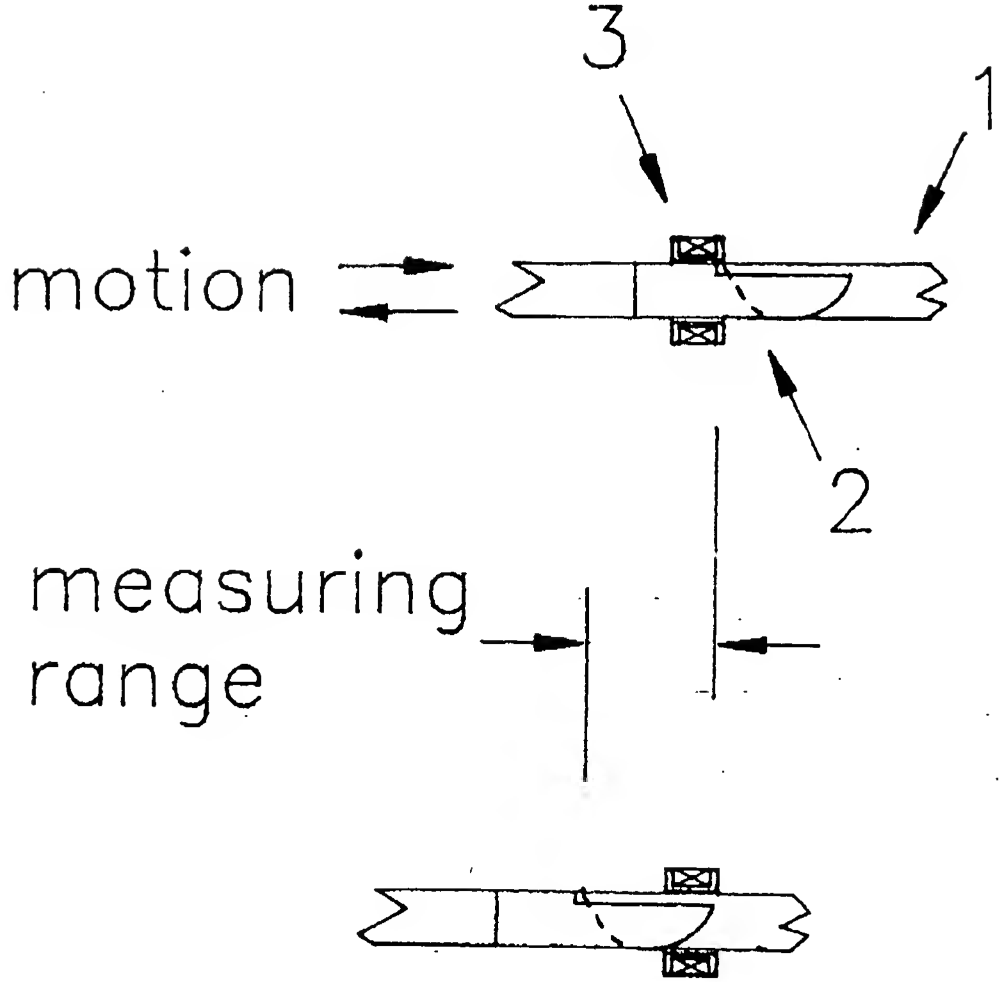


Fig 13